Specification and Production of Concrete Surface Finishes

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PART 1
COMMENTARY ON STANDARD SPECIFICATION

Introduction

This Bulletin was originally produced following the publication of New Zealand Standard 3114:1980 'Specification for Concrete Surface Finishes' to provide information on the background and use of this code, both by the specifier and by the contractor (see also Information Bulletin IB 18 for examples of finishes).

NZS 3114, which was revised in 1987, provides the format which enables the statement of the concrete finishing requirements of the specifier to be translated, through contract documentation, to the contractor. The standard is divided into three parts:

1. Off-the-form surfaces.
2. Exposed aggregate surfaces.
3. Floors, exterior pavements and inverts.

The appendix describes the various blemishes and their probable causes.

The application of the standard permits appropriate qualities of finish to be assigned to all surfaces being constructed, and attention to be drawn to specific needs and requirements to be emphasised to the contractor.

Application of the Standard

Consideration of the method by which the surface is prepared will direct the user to one of the three parts of the specification.

1. Finishes that are formed, and thus mirror the characteristics of the form are "F" finishes and are described in Part 1 – Off-the-form Finishes.

2. Exposed aggregate finishes, whether formed or otherwise are described in Part 2 - Exposed Aggregate Finishes. This section refers to its counterpart in Parts 1 and 3, using a suffix 'E' and also dictates additional parameters that are imposed because of the exposed aggregate nature of the finish.

3. Unformed surfaces are those which are generally laid horizontally, and generally incorporate screeding, floating or trowelling during their production. Such surfaces are described in Part 3 of the specification and are classified "U" finishes.

The specification provides guidance as to the physical characteristics that can be expected to affect the finish and defines limits for the various grades of finish.

The characteristics that are covered by the specification are:

- **Surface Plane Variations**

  Limited by standard measurement.

- **Colour Variation**

  Inherent shade variations are limited by Sample Reference Panels (SRP) defining the standard and a photographic grey scale used to define variation limit.

  Tolerance for other colour variation factors are not defined. SRPs are recommended where colour is important.

  Particular characteristics that cause common distinct problems are highlighted and it is recommended that "precautions be taken to minimise the effect".

- **Physical Irregularities**

  Blowhole frequency and size limits are set by comparison with standard photographic references produced at full size. Tolerances of other physical defects are not set. SRPs are recommended to provide irregularities where physical irregularities are of importance.

  Particular physical characteristics are highlighted and "precaution taken to minimise" or "to prevent the effect" are recommended.

- **The "X" Factor – (for Exceptions)**

  The specification permits the specifier to define variations from the standard by using the "X" factor. Thus the finish will be as defined by the standard except as further defined by the specifier in a particular regard. An example would be an F5 finish where blowhole frequency was not important; the finish could be defined as “F5X – blowholes to be in range 1 to 4”.

Unless the “X” factor is used, the code requirements apply to that finish. The quality of finish, and the value of the finish are to be assumed to be those outlined in the standard.

- ### Sample Reference Panels (SRP)

To quantify tolerance limits of physical irregularities and colour variation, the specification stipulates that the specifier nominate an existing finish that is locally available for inspection (Cl. 104.4.1). Minimum size SRPs (650 x 650 mm) could be produced during the tender period if required by the specifier. The standard recommends that full size sample panels be produced following tender acceptance, and that acceptance of such panels should serve to establish a quality reference for the remainder of the job. The specifier and constructor are recommended to consider the checklists in Figures 1 and 2.

Since the production of the SRP will be, unless otherwise specified, after the contract is awarded, it is important that the specifier clearly define the texture and any special effects he requires at the timer of tender. Such definition may be by reference to existing panels, the use of good quality photographs, including scale, or a combination of both.

The constructor must be confident that the required finish can be produced and should incorporate in his tender price an allowance for all special measures that he considers necessary to achieve the required finish.

When assessing SRPs for acceptance with respect to colour variation, the time from casting will be significant, and should be agreed. The constructor should use the SRP to demonstrate difficulties (e.g. formwork junctions and displacements, mix variation, colour variations due to pressure variation with height, and vibration. It is advisable to include construction joints, rebates, arrisses etc., that will be encountered in the job so that particular features and finishing details can be resolved. Thus the SRP becomes the constructor's checklist for achieving the specified surface finish.

Categories of Finishes

- ### Off-the-form Surfaces

This category covers the concrete surfaces that are primarily dependent on the formwork for texture and finish. As such the most effective results are gained by attention to detail before the concrete is cast. The formwork dimensions, rigidity, joint tightness and texture all become of increasing importance. It is commonly accepted that time spent before casting to ensure the exactness of all of the above is never wasted. Often short-cuts prove very troublesome and more costly in the long-term with significantly more hours, and money, being spent attempting to remedy defects resulting from such short cuts.

The six classifications (F1 to F6) cover all qualities of formed finish. They range from hidden surfaces - (F1) (e.g. foundations, rear of retaining walls, lined surfaces, underwater dam faces), plaster surfaces (F2), exposed surfaces viewed from afar (F3), to architectural and high quality panels (F6). Table 1 outlines the range and requirements incorporated in the standard specification.

Although there is a grey scale included in the Standard there are no specific limits set as to the variations accepted under each finish. It is up to the specifier to determine an acceptable range and to monitor this with a SRP. Any finish that has nominated colour range restriction must be designated with the X suffix and the range specified.

The typical control is the restriction to a range of 2 or 3 shades. For example: Using the shade chart NZS 3114. The SRP sets the mean position of colour shade. In this example let it be shade 3. A specification calling for a range of three shades would permit panels ranging in colour from shade 2 to shade 4.

The greatest contrast for two adjoining panels or areas is shade 2 compared to shade 4.

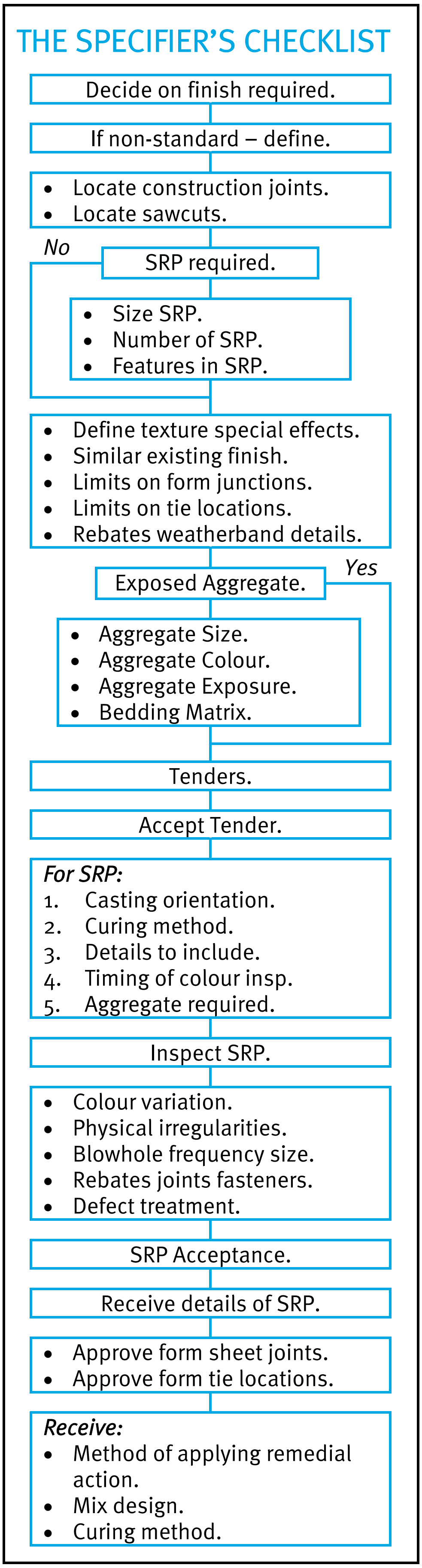

Figure 1: Specifier's Checklist.

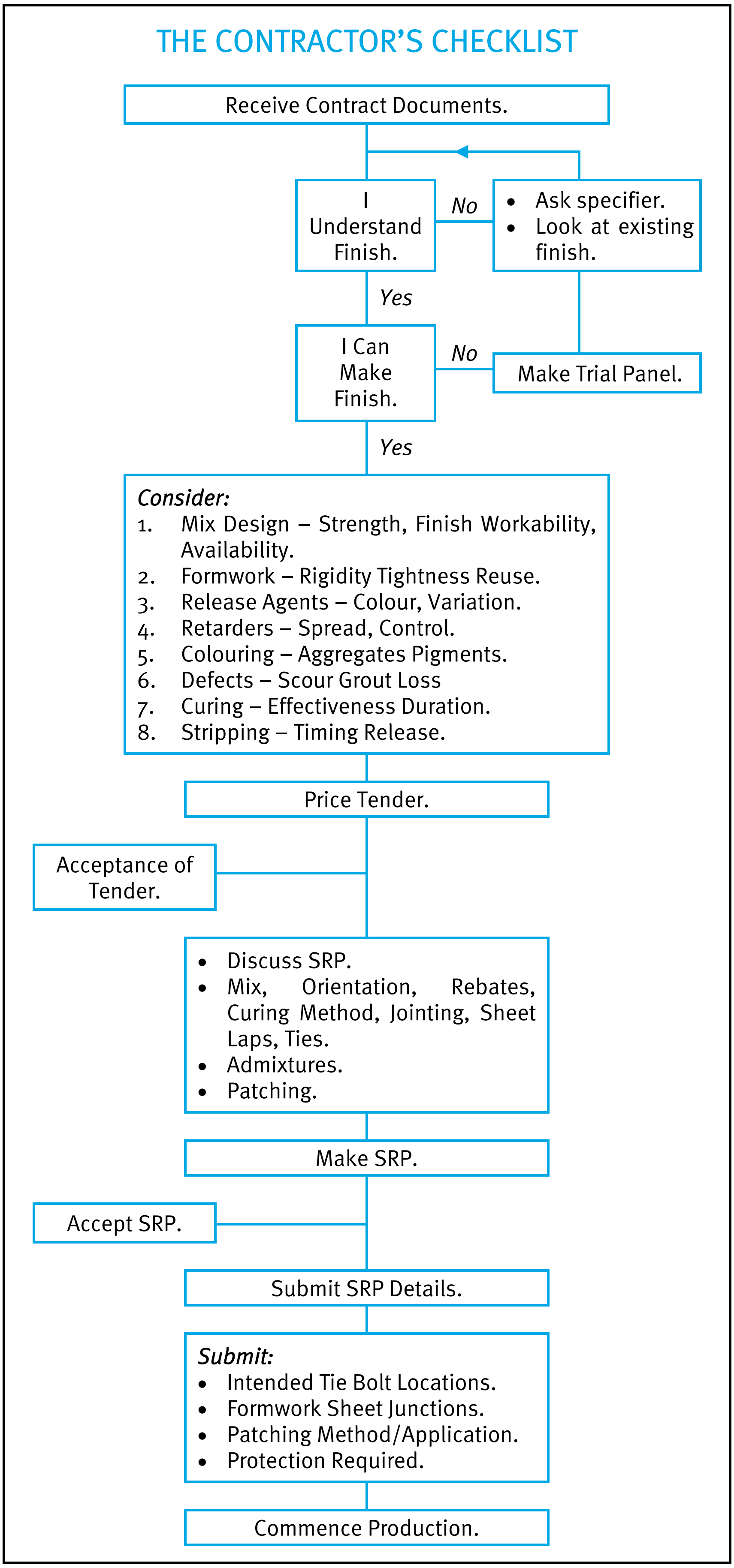

Figure 2: Contractor's Checklist.

Table 1 Summary of specification requirements for formed finishes.

			Surface Plane Variation			Colour						Physical Irregularities								Surface Dressings		
			Sample reference panels required	Abrupt (mm)	Gradual (mm)	Discoloration	Contamination	Dusting	Retardation	Efflorescence	Acceptable Shade Range*	Blowhole Limits	Formwork Deflection	Grout Loss/Scour	Form Tie	Sheet Location	Scabbling	Chipping	Spalling	Filling Composition	Method	Action
F6	Surface of high importance. Alignment, appearance very important.	Architectural or feature panels. High velocity water channels.	R	1 3	4	P	P	P	P	P	*	2	2 mm 1/360	E	A	A	P	P	P	S	A	A
F5	Structural surfaces of importance. Frequent close scrutiny.	Walls, panels, columns, beams, piers, soffits, parapets, railings, offices, foyers, public areas.	R	3	6	P	P	P	P	P	*	3	3 mm 1/270	P	A	A	P	P	P	S	A	
F4	Structural surfaces of moderate importance observed frequently.	Walls, panels, columns, in secondary areas (e.g. basements, car parks).	R	4	6	P	P	P	P	P	*	4	3 mm 1/270	P	A	A	P	P	P	S	A	
F3	Exposed surfaces not subjected to close scrutiny.	Building and engineering structures viewed from afar.		6	6			P		P		5		P			P	P	P		A	
F2	Keying surfaces for plaster and other thick coatings.	Interior and exterior surfaces to be coated.		6	6			P		P		7										
F1	Roughness permitted: Fill tieholes, defects. Colour variation permitted.	Concealed surfaces. Foundations, lined walls, upstream dam surfaces.										7										

R = Required S = Specifier to Stipulate P = Precautions to Minimise Effects E = Prevent Occurrence A = Approval Required

* If specified shade range required, the finish must be designated with X suffix.

Tighter control can only be exercised with a range of two shades which is difficult to administer since the concept is that the SRP sets a mean about which there can be lighter and darker shades. Consequently unless the SRP mean shade is literally "between" two shades, interpretation in a light/dark variation can be difficult for a range of two.

- ### Exposed Aggregate Surfaces

As defined, surfaces enter this category if they have exposed aggregate on their surface. The specification extends the classification from Parts 1 and 3 with an "E" suffix. Thus finish F5E is a formed finish to F5 tolerance limits with exposed aggregate surface texture.

The primary extension relates to the selection and uniform end result of the aggregates to be exposed. In all cases SRPs are required to provide a means of compliance.

When using exposed aggregate surfaces, the specifier must consider and define the following:

The aggregate:

1. Weathering and staining characteristics.
2. The colour and mineral type.
3. The source of the material.
4. Exposure depth.
5. Angular characteristics required.

The matrix:

1. Colour.
2. Texture.
3. Thickness.

Because exposed aggregate finishes will only be used where the surface is visible, the formed finishes F4, F5, F6 are extended to accept the exposed aggregate standard of F4E, F5E, and F6E. Exposed aggregate may also be used in unformed surface, resulting in a shallow texture. Thus U5 finish may be applied to exposed aggregate unformed surfaces as U5E.

- Unformed Surfaces

This category of concrete surface finish extends to all floors, pavings, slabs and inverts. These surfaces remain exposed when concrete casting is completed. The surface results from screed, float or trowel action, and texture sometimes provided by additional measures such as brooming, raking, grinding or scabbling.

There are eleven standard finishes specified in the code. They relate primarily to the texture required for the surface to perform its intended function. The derivation of a particular class of finish frequently requires the surface to proceed through lesser classes (i.e. a U5 broomed finish is usually screeded to Class U1 and floated to Class U2 prior to the final texture being applied). The classifications for unformed finishes are shown in Table 2.

The durability required of the slab often dictates the finish specified, with U3, U4 and U11 (trowelled, machine screeded and ground finishes) increasing the toughness of the surface.

The specification tolerances with respect to colour and physical irregularities are tabulated and vary somewhat depending on location and end use. Abrupt deviations are to be less than 3 mm in all finishes but should be avoided where carpets and thin tiles are to be used for floor coverings. Gradual deviations are within 5 mm over 3 m for most classes of finish. The problems of plastic cracking and crazing are more common with the large exposed surface areas involved. The specifier must stipulate the spacing and requirements of joints to minimise these effects.

Materials and Workmanship

The standard requires that the selection of the material and composition of the concrete should take into account the surface finish required. The finish will depend on many factors including concrete grade, cement content, workability, formwork, release agents, placement technique, compaction, curing methods, protection, finishing method and dressing.

When coloured aggregates or colour pigments are to be used, it is recommended that sufficient quantities be stockpiled from the outset of the work as variations in colour and composition are more apparent in this type of finish.

NZS 3114 is a performance specification, and the constructor is responsible for determining the method to be used to produce the specified finish. The appendices of the specification are intended to provide some insight as to causes of defects of the surface. The constructor is advised to take precautions against particular defects in selected instances.

The constructor is required to provide adequate protection for all surfaces from the time of casting, until the completion of the job. This should include handling during transportation, erection and all subsequent operations. Where units move beyond the control of the constructor, as would often be the case with precast panels, protective measures required should be detailed and undertaken by the recipient of the units.

Table 2 Classes of floor, exterior pavement and invert finishes.

Class	Finish	Technique	Examples
U1	Screeded	Hand sawing motion with straight-edge or mechanical vibrating screed.	Finishes covered by backfill or concrete. Footpaths, yards and driveways. First stage for placement.
U2	Floated	Wood or bull float, or both. Generally manual but power driven equipment may be used.	As for U1 where a higher standard of finish is required. Floors to receive carpets with underlay or similar coverings. Inverts of syphons, flumes, floors of canal structures, spillways outlet works and stilling basins. Surfaces which are intended for use by ambulant or wheelchair-bound persons.
U3	Trowelled	Manual or mechanical steel trowelling of floated finish after concrete is sufficiently hardened, to prevent excess fine material and water being worked to the surface, may be done in one or two stages depending on degree of smoothness required.	Direct wearing floors such as in factories, warehouses and processing plants. Floors to receive thin sheet coverings, carpet and similar coverings. Inverts of water, tunnels and tunnel spillways. Not generally used for pedestrian or vehicular traffic where a smooth finish could be dangerous in icy or wet conditions. Is not suitable even when dry, for surfaces which are intended for use by ambulant disabled or wheelchair-bound persons. See U2.
U4	Machine	Vibrating or oscillating screed or vibrating plate, or both, which may be supplemented by long handled metal, wooden, or rubber floats.	Used for durability where resistance to erosion and cavitation under action of high velocity water is especially required: and as first and second stage finishing for roads and airfield pavements prior to texturing with U5, U6 or U8 finishes.
U5	Shallow Textured	Hard or soft bristled brooms.	Footpaths, yards, driveways, roads, pavements for aircraft.
U6	Deep Textured	Wire broom or rubber tyning.	Surface to receive a subsequent textured bonded concrete topping. Roads and runways where greater frictional resistances are required than can be obtained by U5 finish.
U7	Grooved	Saw cutting or flailing by mechanical means.	Treatment to existing roads and runways to provide frictional resistance and drainage paths for run-off to minimise aquaplaning.
U8	Grooved	Mechanical grooving the fresh concrete surface after compaction and surface screeding techniques.	Roads and runways.
U9	Scabbled	Mechanical hammering of hardened concrete.	Can be used on any pavement surface to produce a textured effect or to reduce high surfaces to the correct level or to rectify out-of-tolerance pavements.
U10	Special Textured	The use of equipment to give special effects.	Architectural effects on pavements and slabs, produced by rollers with drums of expanded metal, or profiled tempers on screedboards, and the like.
U11	Ground Finish	Low speed coarse stone grinding to remove thin weak surface layers/minor ridges and to produce an even "glasspaper" textured surface, that is, not a polished surface. Used as a second state finish to U2, approximately 36 to 48 hours after laying.	Direct wearing floors such as in warehouse.

PART 2
PRODUCTION OF CONCRETE SURFACE FINISHES

General

Various types and uniformities of finish have been discussed in Part 1, with attention being given to the finish that is required. To achieve the defined finish it is essential that a systematic approach be adopted, using consistently good quality products. This includes good quality moulds, forms, compaction equipment and concrete.

All finishes require care and attention during casting. Selected finishes require additional attention and treatment either before, during or after the concrete is cast. The classification relating to **when** the attention is required is used in this Bulletin as follows:

Type A: **Before casting.**
The finish is the mirror of the mould.

Type B: **During casting/setting.**
The exposed surface is treated.

Type C: **After casting.**
The finish is obtained from the hardened surface.

Some methods apply to both insitu and precast work, whereas some cannot be obtained from insitu concrete.

Variations in Colour and Texture

The primary characteristics of concrete that relate specifically to its surface are that of colour and texture.

The New Zealand Standard NZS 3114 - 'Specification of Concrete Surface Finishes', provides the means of specifying what colour and texture variations are acceptable in particular circumstances.

Common physical and colour related blemishes are itemised in the appendices of NZS 3114. The tables have been incorporated here in Appendix A.

In addition Table 3 has been prepared to highlight the features that require particular attention when manufacturing concrete products, and possible defects that may result.

Table 3

Item	Feature	Defect
Formwork	Preparation Absorbency Roughness Cleanliness	Alignment, grout loss, joint stepping. Crazing, colour. Scaling, chipping, spalling. Discolouration.
Release Agents	Effectiveness Purity Compatibility	Scaling, chipping. Local discolouration, shade variability. Retardation.
Mix Design	Low strength Excess cement Proportions	Scour, scaling, chipping. Crazing. Blowholes.
Placement	Inadequate ventilation Excessive drops Excessive vibration Non-uniform	Air pockets, honeycomb. Segregation, steps. Crazing, laitance. Plastic cracking.
Curing	Impurities Inadequate Uneven Excessive	Contamination. Crazing, warping. Colour variation, efflorescence. Abrasion, scour.

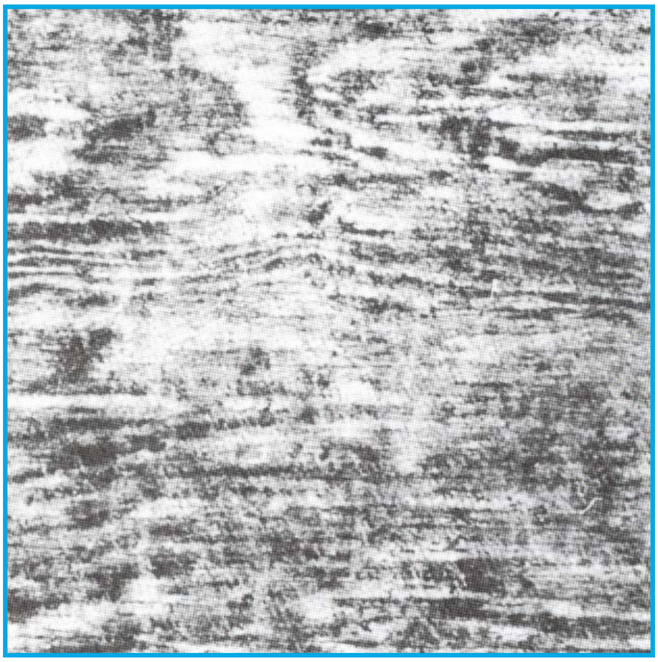

Figure 3: Hydration discolouration (half scale size).

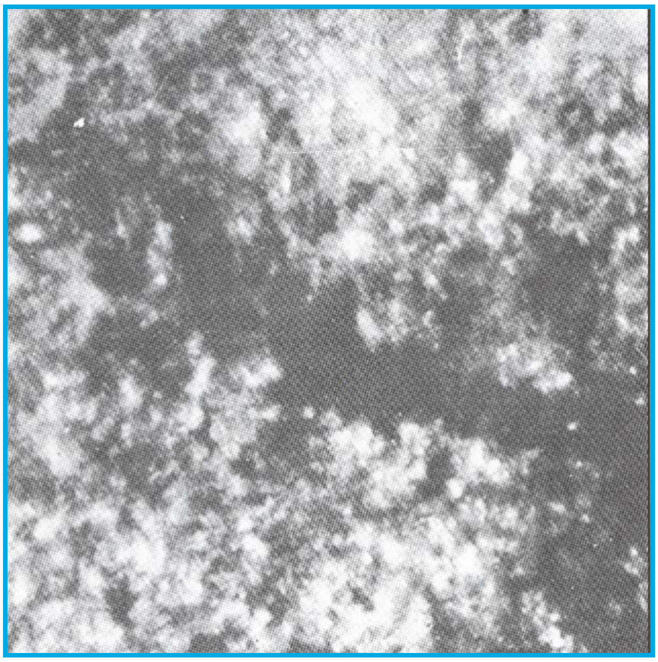

Figure 4: Colour variations often associated with impermeable form face (half scale size).

Determination of Finish

Treatment Before Casting – Type A

- ### Off-the-form Finish

This finish is the most common, often being referred to as "fairfaced concrete". The finish is produced by the pattern of the concrete form being mirrored on to the concrete surface. It may be the most economical form of production, provided adequate measures are taken to avoid the need for remedial work after stripping. Such measures demand the following precautions:

1. Attention to detailing, with adequate provision for joints, edges, corners, drips and other weathering details, and adequate measures to allow form release and removal;

2. Clean, well maintained and watertight forms (see also IB 29 and 41);

3. A concrete mix with adequate cement content, low water/cement ratio and high density;

4. Adequate consolidation and uniform curing to ensure uniformity of colour and texture;

5. Protection to minimise chipping and damage subsequent to casting.

The finish may be **flat smooth** (i.e. formed from sealed wood, steel, sealed concrete, fibreglass etc.) or patterned smooth (i.e. fluted, sculptured or board finished. The **patterned smooth** finishes tend to mask many of the limitations of the flat smooth finish. They are however, more expensive to form, requiring additional treatment to the flat form finishes.

Major blemishes in the concrete surface relating primarily to the composition of the form face are:

- Hydration Discolouration: This relates to the absorbency of the form face. Variations in absorbency within the material itself, e.g. springwood/ summerwood or variations caused by wet concrete pressure will result in hydration staining.

  A further problem relates to the use of materials that are completely impermeable such as steel and HDO plywoods. These tend to give dark polished areas caused by form face vibration during placing of concrete (Figures 3 and 4);

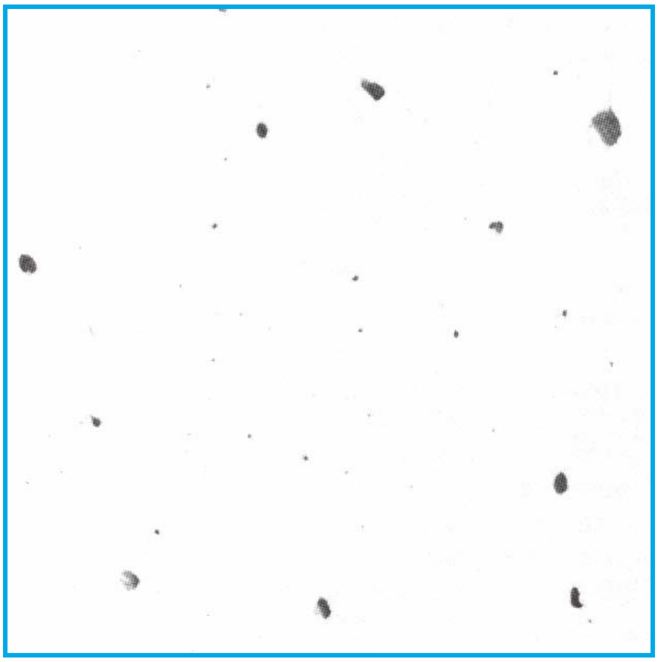

Figure 5: Blowhole in concrete surface usually less than 10 m notional diameter (half scale size)

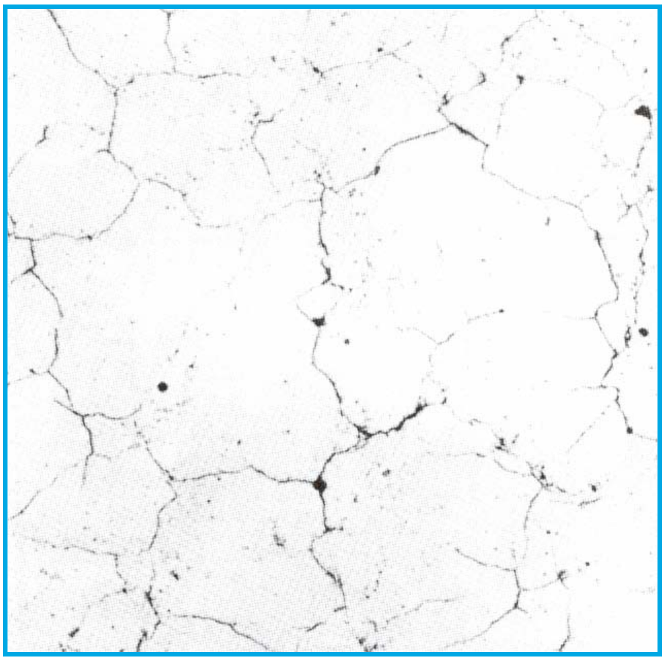

Figure 6: Crazing pattern of fine network of shallow cracking (full size)

- Blowholes: Form faces which have an impermeable surface tend to have a higher incidence of surface blowholes. In this regard plastic faced ply whilst producing a smooth surface is likely to have a higher incidence of blowholes (Figure 5);

- Crazing: Form faces which have a glazed smooth or polished impermeable surface can lead to fine cracking. As will be seen from a comparison of these factors, specific provisions to avoid blowholes may lead to hydration discolourations and vice versa (Figure 6).

- Characteristics of Form Materials

The range of **patterned and smooth** textured finishes is considerable. Some examples of materials used to imprint patterns are discussed.

- Timber: Sand blasted to raise the grain, rough cut; bevelled or champhered for fluting; clapboard fashion for bold texture etc.

  Smooth board surfaces; For the smoothest possible board marked finish only dressed tongued and grooved boards or grooved boards with loose tongues and plastic foam strips should be used. The tongues hold adjacent boards in alignment and the plastic foam strip prevents leakage at the joints which otherwise would form fins or discolouration accentuating the joint lines. The boards must be of uniform thickness so that there will be no offsets at the joints.

  Rough board surfaces; Where no joints between boards are to be emphasised the procedures are as above.

  Featured joints; Raised joints between adjacent boards can be emphasised by a chamfer of say 10 mm on a 25 mm board. Mechanical damage however is very likely with horizontal raised joints. A better feature therefore is produced at the joints between boards. The indent is produced by fixing a fillet on the board face at the joint position.

  Profiled surfaces; When deep profiled surfaces are to be produced, timber formers should have a draw of 1 in 4 for softwood and 1 in 6 for hardwood.

  General comments; To achieve maximum uniformity of colour, timber should be pre-treated by thorough oiling **before** the first use. Failure to effectively seal the first use will result in a lightening colour effect after each successive use.

- Plywood: Plain construction plywood; textured plywood; HDO plywood.

  Exterior grade plywood should be used. Whilst sizes range from 3 mm to 22.5 mm, the most commonly used in sheeting are 9.6, 12.5, 17.5 and 22.5 mm. The advantages of plywood over timber sheeting are that it is rapidly fixed, can provide large surface areas without joints, has high resistance to impact, can be nailed close to the edge and is considerably more stable in relation to moisture shrinkage and swelling effects.

  For forming curved surfaces the typical radii that can be achieved with 6 mm plywood bending parallel to the grain is 600 mm, and across the grain 380 mm. Typically, 12.5 mm plywood can be bent to a radius of 2.4 m and 1.8 m respectively.

  In the use of plywood it is extremely important to note that its strength relates to the direction of the grain of the outer plyface. Panels should normally be used with the grain parallel to the span of the sheet. Severe reductions in load capacity and increased deflections will occur if used with outer ply face grain running at right angles to the span.

  Surface coatings reduce the colour variations on the concrete face as well as extending the ply's use. In particular, colour variations due to concrete pressure are less marked.

  As the surface coating becomes more impermeable, such as a plastic faced sheet – HDO – then there tends to be an increase in the formation of blowholes and a possibility of crazing. Relative number of reuses is, however, increased.

- Steel: Steel forms produce concrete of uniform colour provided they are protected adequately from rusting and form face vibration can be reduced; however, because they are impermeable, some blowholes are inevitable. A high standard of site care and maintenance of steel forms is necessary to avoid rust discolouration and distortion of the edges of pans and panels. The practice of painting steel forms to protect them from rust is not recommended because eventual failure of the paint causes unsightly scabbing. Because of the flexibility of sheet steel facing, special attention should be paid to jointing, to avoid high vibrator amplitudes and leakage during vibration, and to ensure that the steel sheet is of sufficient thickness to limit deflection between supports. The selection of a mould oil with rust inhibiting properties is of prime importance. Neat oils with surfactant are usually more suitable than mould cream emulsions.

- Oil tempered hardboard: Oil tempered hardboards are almost impermeable and provide concrete of reasonably uniform colour although some surface blowholes are inevitable. Their life is considerably shorter than that of most other linings.

  A recommended procedure is to wet the back of sheets and stack flat for 48 hours before use. Preferably the sheets should be centre pinned in order to reduce buckling tendencies. The material should be oiled before use, cleaning down should take place using a stiff brush and cold water before re-oiling for use.

- Neoprene and rubber linings: Rubber sheet linings may be used to create textured or profiled surfaces. The surface is generally of uniform colour although having some blowholes. For fixing in vertical positions linings can be glued or tacked to the backing sheet.

  Thick sheets may be lightly tacked since the fluid pressure of the concrete is sufficient to expel any air between shutter face and rubber lining. Thin sheets should be stuck to the backing shuttering.

  Mineral oil based release agents must **not** be used since these soften the rubber. Castor oil or lanolin are suitable release

Figure 7: Use of cement board as formwork liner to produce an even coloured textured finish.

agents. On shallow profiles no release agent is necessary. It is recommended that concrete be allowed to harden for 48 hours before demoulding when not using a release agent. The rubber liners should be cleaned down with water brushing after striking and then lightly oiled with vegetable or animal oil.

- Glass fibre reinforced plastic – GRP: Moulds of GRP produce low relief patterns with a smooth eggshell like finish. Blowholes may present problems and can be minimised by using mould oil. There is also a higher risk of producing panels where mottling and surface crazing are evident if the GRP surface is highly polished. Matt finishes of GRP give less colour variations and less risk of crazing.

  Formwork should be left for 48 hours before striking. The concrete will have a high gloss finish which slowly disappears with time due to carbonation. The GRP form should be wiped clean with damp or oily rags. Any stubborn concrete pieces left should be removed with a timber scrapper.

- Glass fibre reinforced cement – GRC: GRC permanent formwork systems are now available in New Zealand. Low profiled shapes can be sprayed to form sheeting, which often has sufficient structural properties to require only the minimum of structural support from a backing system.

  The advantage of the material is that it allows a highly impermeable surface to be produced; cast face down avoids blowholes so the surface is very suitable for external decoration such as painting. The material is of thin section 6-12 mm usually, thus allowing full potential of insitu casting to provide the structural continuity needed in seismic design. As a low profile material it can be used without decoration.

- Special applications. Cement board such as Hardiflex has been successfully used to produce a textured finish with a high degree of colour control (Figure 7). Various other materials have been used to create special effects, e.g. rope, plaster casts, urethane rubber etc.

- Surfacings Applied in the Mould (Restricted to Precast Products).

  The texture is created by material other than concrete (e.g. brick, glass, cobblestones, large aggregates etc.) being hand placed into the bottom of the mould.

  Generally a process known as sand-bedding is used. The bottom of a horizontal slab form is covered with a layer of sand, the depth depending on the size of aggregate to be used, and the amount of exposure. Large aggregate can be exposed as much as 50 mm. After the sand has been spread, coarse aggregate particles are hand-placed in the sand, the stone and sand gently sprayed with water to settle the sand, then the structural concrete is placed. When the concrete reaches the necessary strength, the unit is removed from the mould, raised to a vertical position, and vigorously washed with water to remove the loose sand and expose the stone.

  This method can be used for any size of aggregate, and is especially suitable for exposing the larger sizes (Figure 8).

  The technique can be applied in particular to tilt-up slab construction.

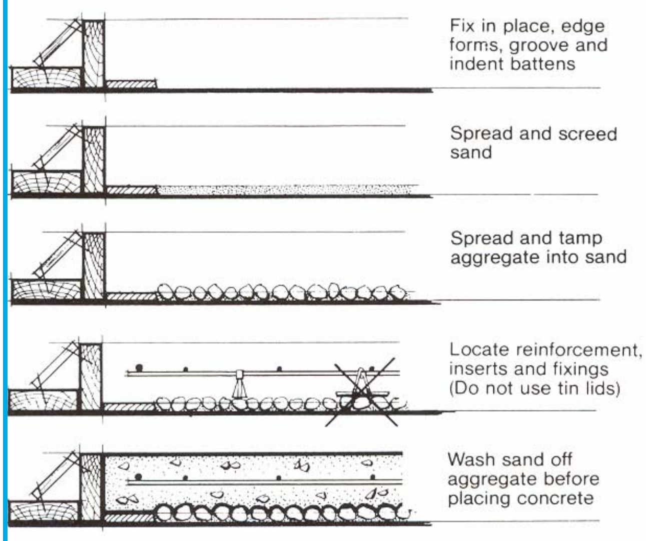

Figure 8: Sand bed technique for face-down special finish casting.

The aggregate transfer method can be used for small areas of vertical casting. Aggregate is pre-selected and glued to a backing sheet which is placed in the mould and subsequently stripped off after casting has embedded the aggregate.

- **Surfacings Applied After Casting** (Precast Only).

The finish is that of the facing material with the concrete providing strength and bond to the element (ceramic tile, brick, or stone).

Attention must be paid to the compatibility of the texturing material with the concrete backing. Aspects requiring investigation include different thermal expansion characteristics, (especially for dark coloured materials), the effects of humidity, stability under atmospheric attack, and chemical compatibility with the concrete backing.

Where significant differences in movement are expected between the facing material and the concrete, a complete bondbreak can be incorporated, and the facing attached by mechanical fasteners. Recognition of the need for independent movement must be made. Usually, cut stone faces have little resistance to bowing, and chipping or cracking can readily occur. This necessitates careful attention to mix design (a low water and cement content) and slow, humidity controlled curing. It is highly desirable that samples be prepared, and behaviour tests undertaken to verity the behaviour of the composite unit.

- **Wet Off-the-forrn Finish**

This method is not commonly applied in New Zealand. Its principal advantage is that the mould becomes rapidly available for re-use. The concrete is cast face down into the mould, a pallet is fastened on top of the mould which is inverted and removed leaving the concrete on the pallet to cure.

Treatment During Setting – Type B

- **Face-down Treatment**

This process involves the treatment of the mould with a chemical surface retarder which slows the setting process of the concrete which comes into contact with it while allowing the body of the concrete to gain strength. The slowing of the surface setting allows the form to be struck and the soft material to be removed by washing and/or brushing exposing the aggregate. Finishes vary from a light exposure (cement only removed and edges of closest coarse aggregate exposed) through a medium exposure (cement and surface sand removed) to a deep exposure (up to 12 mm surface removed, coarse aggregate is the predominant surface feature).

The shape of the aggregate, its position following consolidation and the depth of etch will determine the surface appearance. The appearance will therefore vary to some degree depending on orientation of the surface and on the aggregate shape. This should be taken into account for returns and exposed vertical sides of forms.

The retarder is usually in a liquid form. It must be applied uniformly to the formwork usually with a roller, although it may be spray applied.

If the formwork has varying absorbency (e.g. timber or ply) this can influence the degree to which the retarder will be effective when it comes to exposing the aggregate. This effect can be reduced by sealing the formwork with a

Figure 9: Hand test carried out to check when a concrete surface is ready for fine trowelling. The upper hand shows the ideal conditions.

barrier paint before coating with the surface retarder.

When the formwork is used for the first time two coats of a suitable retarder should be applied and for each subsequent use one application should be enough.

The time of year, and particularly the temperature of the concrete, will have an important effect on the time at which formwork should be removed and the surface treated. Experience suggests that the sooner the formwork can be stripped and exposure commenced the greater chance there will be of success. On no account must exposure of the aggregate be delayed after stripping otherwise the cement will set and harden.

Care must be taken when casting vertical elements that the concrete does not discharge directly on to a retarder-treated surface, as this will both remove the retarder and contaminate the concrete mass. Similarly, vibrators should not be held in contact with the form surface as this will also remove the retarder. Rain may also remove the retarder before casting.

The selection of which type of retarder to use will depend upon the time to stripping, the depth of etch required and the concrete mix used. Proper planning is required to ensure that the retarder remains operative sufficiently long to allow stripping and exposure to occur. Generally, a wash down with 10% hydrochloric acid is recommended at seven days to remove cement bloom, followed by a general surface wash down.

- Face-up Treatment

Treatment of the exposed surface is most common in slabs, floors and inverts. It also applies to precast units which are cast horizontally.

- Smooth flat: Obtained by screeding, floating and subsequent trowel finishing. Most common form of finish to floors and inverts. Timing the processes according to degree of set is very important.

  Finishing should not be attempted where bleed water has accumulated on the surface, nor should these areas be dried by sprinkling with cement. If natural evaporation or absorption is too slow, the water should be removed by draining, mopping or by dragging a piece of hessian across the surface.

  Trowelling should not take place until the surface is hard and dry enough for a hand not to imprint the surface or pick up a significant amount of cement paste. This timing varies very considerably with the temperature (Figure 9). In summer it may be only 1-2 hours, in winter it may take 5 or 6 hours. Techniques like vacuum de-watering, described in CCANZ Information Bulletin 01, help overcome the timing problem.

  It is possible to produce different textured finishes by stopping at the screeding stage or proceeding to the floating stage when, for example, a woodfloat finish is formed. Texturing is described in a later section.

- Exposed aggregate: The process primarily involves a brushing and washing method during the concrete setting process. Occasionally a retarder application and after-set washing may be used. The timing of the brushing and washing method to expose aggregate depends on the mix, the water/cement ratio, the size of the member, the type of cement and the time of year. With ordinary portland cement mixes it will usually be found that the most suitable time is between 2 to 6 hours after casting.

Good exposure of the aggregate is obtained from a gap-graded concrete, often where the 10–2.36 mm (3/8 in – No. 7) sizes have been omitted from the mix.

When using a tilt-up mould the mould should be slightly tilted, with the water and brushing starting from the top. Different types of broom will give different depths of texture.

Uniformity of the finish depends to a very great extent on the degree of supervision at all stages of the job and it cannot be over-emphasised that a high standard of workmanship is essential for an acceptable finish.

A clean down using 10% hydrochloric acid is usually required to remove any cement bloom and the surface washed down. The resulting texture differs from the "Face-down" technique since the coarse particles tend to migrate to the bottom of the mould during consolidation.

The exposed surface may be seeded with larger size aggregates. This should be done after consolidation and before washing if required. Control of the depth of aggregate exposure is possible by rolling the seeded particles into the surface.

- Decorative/textured - broom or pressed finishes: A shallow texture finish can be produced by scoring the floated finish with the common bass broom with hard or soft bristles depending on the degree of frictional resistance needed. Transverse striations are produced by drawing the broom across the surface in a continuous movement so that the bristles trail the head of the broom. It is emphasised that this is done after bleed water has evaporated to achieve the best striations.

  A deeper striation can also be formed for greater frictional resistance. Two rows of spring steel tapes have been found to be the most suitable for the "bristles" of the broom. A suitably designed lawn rake with rubber tynes can also produce a deep texture. The tynes need to be curved with a minimum pitch of 12 mm, 15 mm being preferable and 18 mm excessive. It is essential that the tynes be so shaped as to induce aggregate into the ridges so formed rather than surface laitance only.

  A twin roller with drums of expanded metal each about 125 mm diameter by 1m wide or a single pipe, 300 mm diameter x 3.5 m wide and weighing about 44 kg/m around which sheets of patterned rubber or expanded metal can be wrapped, can be used to give a satisfactory ribbed pattern of a texture of average depth 5 to 6 mm. General purpose diamond mesh with 300 mm x 12 mm apertures is considered to be satisfactory, but the protruding fins formed by the apertures tend to consist of weak mortar and would be quickly worn down by traffic.

  Imprinted patterns can be formed by rollers or pressing in special formers into the wet concrete.

  Deep surface sculpture of exposed surfaces using polypropylene concrete is possible because the high air entrainment and fibres will support deep texturing at the time when the concrete is still in a very plastic state (Figures 10 and 11).

- Coloured Concrete Surfaces

Permanent colouring of concrete surfaces is achieved by adding colouring pigments during the batching process. Another popular method of providing permanent colour to concrete surfaces is to use and expose coloured aggregate to the concrete surface.

For economy, both methods are most commonly used as a surface topping (i.e. up to 50 mm from the surface) using both the "face-

Figure 10: Polypropylene fibre concrete showing its ability to hold shape in its wet state.

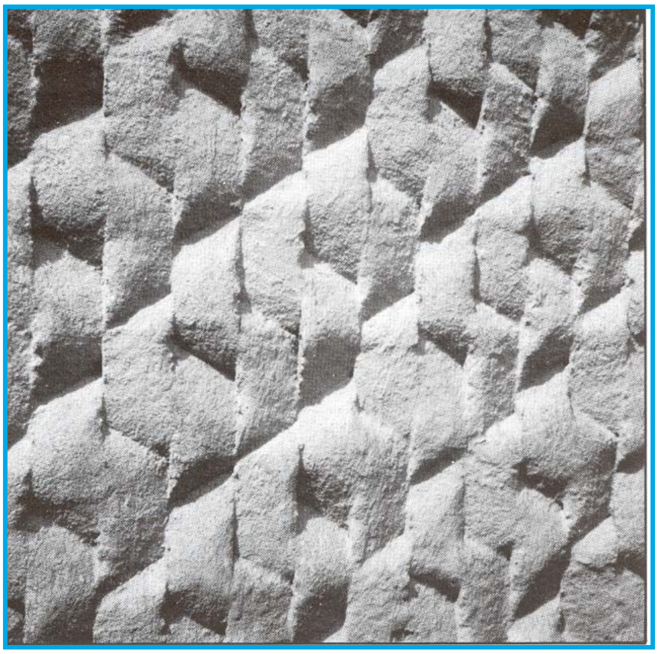

Figure 11: Textures and patterns achieved using polypropylene concrete.

down" and "face-up" casting techniques (conventional concrete is employed as backing to such units). The use of the face down technique is limited to precast units.

- Pigmented concrete: The pigments are added to the concrete during batching and operate on the binder (i.e. the cement) while the aggregate particles remain unaffected. The use of coloured aggregates is not necessary although contrasting aggregate/binder colours can be used to good effect with exposed aggregate finishes.

  Care must be taken when selecting colouring pigments which must remain colour stable when exposed to sunlight and weather. Water soluble salts within the pigment may accentuate efflorescence and should be avoided.

  The pigments are most commonly derivatives of Iron Oxide (reds, browns, yellows and blacks), Chrome Oxides (greens and blues) and Titanium Dioxide (white).

  To achieve maximum uniformity of colour it is vitally important to have:

  1. Consistent batching of all materials in the concrete, including the pigment and water;
  2. Consistent mixing times;
  3. Consisting striking times for face formwork where used, or consistent trowelling techniques for horizontal surfaces. Different trowelling times or applications can give colour variations;
  4. Consistent curing methods used throughout job. Variation in curing can give rise to serious colour discrepancies.

- Coloured aggregates: Both colour and texture can be added to concrete surfaces by using coloured aggregates which are exposed. The methods and depth of exposure are the same as those described elsewhere (i.e. retarder, brushed, sand embedded etc.).

  The significant differences between this type of colouring and pigmented concrete is that the surface usually has texture as well as colour. The exception is when the hardened surfaces are mechanically ground (see later section) thus exposing sections through the aggregate.

It is important that the coloured aggregate used is of consistent colour and composition. It is recommended that sufficient coloured aggregate is stockpiled at the beginning of the job to ensure this consistency. A list of generally available coloured aggregate is given in IB 11.

Treatment After Casting – Type C

- ### Relatively Smooth Surfaces

  - Acid etching: The finish is achieved by washing the hardened concrete surface with an acid solution (10% hydrochloric acid). This will react with and soften the cement paste which is removed by washing. Features which require consideration when this technique is applied include stability of the aggregate under acid attack, the protection of hardware and the protection of surfaces not to be treated.

    The acid action is noticeably greater on poorly compacted concrete. Thus uniformity of compaction and mix are influential in attaining consistent texture. Although the depth of texture is dictated by the time that the acid is left on the surface, it is usual to expose the coarse aggregate (between 5 and 10 minutes) for best consistence of result. During this time the reaction gives off considerable fumes making ventilation important.

  - Light blasting: Blasting techniques involve the use of sand, or other abrasives, to remove the surface of the concrete. The abrasive is ejected by hose directly on to the surface, with the depth of exposure being dictated by the type of abrasive, the pressure used, the distance from the surface and the age of the concrete. On concrete less than 3 days old exposure rates of 3.75 m^2 – 5.5 m^2 per hour can be achieved.

    A serious consideration is the degree of clean-up of spent abrasive. This is minimised if air or water is used as the abrasive, which is possible for light blasting if it is undertaken early. The degree of uniformity is related to the depth of texture required, with the deeper texture being easier to attain. Light blasting, with a single cover depends heavily on the operator's consistent concentration.

    Variations in the surface such as airholes, joint lines, etc, are easily accentuated with blasting and extreme care is required. It is a common misconception that abrasive blasting will improve the appearance of poor quality concrete. It will remove many colour variations but may accentuate physical defects in the surface. It is important that realistic shapes be incorporated into the standard sample so that such effects can be recognised.

    Grit or sand blasting should be recognised as having a dulling effect on the aggregate. It is however more stable than many alternative forms of treatment, the colour and texture remaining substantially constant during weathering.

  - Honed or polished: Grinding of the concrete surfaces, usually with mechanical equipment, results in a honed finish. The surface of the aggregate is ground smooth and dominates the concrete surface. Continued grinding, with the addition of fine grit, can result in a highly polished surface. This technique is expensive and demands a high degree of craftsmanship. For economy, honed and polished surfaces are usually restricted to flat areas where access of the grinding equipment can be achieved. It is often used in conjunction with other techniques to provide very satisfying results. Recommended bay sizes are shown in CCANZ Information Bulletin IB 26.

    Since it is the aggregate itself being modified by this process, particular attention must be paid to the maximum size and hardness, which affect both the final appearance and the cost of the finish.

  - Painted: This process is for aesthetic reasons not being generally required for the concrete itself. It is often desirable to permit a lesser quality of finish, and cost savings can be made by painting exterior surfaces. Acceptable results can also be achieved by painting internal surfaces.

- Relatively Rough Textured Surfaces

  - Medium and heavy sand blasting: Continued blasting will produce any depth of exposure required. The surface will be dulled and rounded however, and this should be recognised. For deep exposure, retarder or face-up water washing may be used initially.

  - Mechanically fractured surfaces: Mechanically fractured surfaces are the result of mechanically removing part of the off-the-form concrete surface by scaling, bush-hammering or tooling.

    Removal of the skin of hardened cement paste from the face of the concrete reveals rather than masks any imperfections, whether they be from poor formwork design or lack of attention to mixing, placing and compaction of the concrete. This cannot be emphasised too strongly as the most common misconception is that tooling will improve the appearance of poor quality concrete.

    In general, to produce a satisfactory tooled finish, it is first necessary to produce a good plain finish. It is important to obtain complete compaction and to avoid any segregation for when the mortar skin is removed these defects are noticeable to a greater depth than before.

    Colour variations on the mortar skin caused by the use of an absorbent lining are not important as this discolouration does not penetrate deeply. Consequently any type of form face material may be used as long as special attention is paid to rigidity at all joints and the avoidance of leakage through the formwork. The final finished appearance will depend upon the detailed design, the composition of the concrete and the method used to expose the aggregate.

    With all methods of bush hammering, the most satisfactory aggregates are those derived from crushed rocks as opposed to natural gravels, and the most suitable mixes are those in which the aggregate has not more than 10% of 10–5 mm (3/8–3/16 in.) materials in the coarse fraction. Tooling produces a homogeneous surface in which the particles of coarse aggregate are not seen individually. By breaking particles of aggregate and removing the protective fine cement-sand from the face, it makes the concrete more absorbent. Therefore, additional cover to the reinforcement should always be provided.

    Tooling is not normally suitable for arrises, and these are frequently protected by battens during tooling. This leaves a plain margin to the bush-hammered surface.

    Whilst tooling should not be commenced until the concrete has gained sufficient strength to resist serious spalling, it is possible to start after 1-2 days. The earlier the start obviously the greater the rate of production. By leaving the tooling to the latter stages of the job, the work takes considerably longer to execute but has of course the advantage of removing surface staining that might have occurred during construction at higher levels of the building.

    Scaling is achieved by using a pneumatic scaler fitted with three piston-headed chisels that rotate and fracture the concrete surface. The result is a fine nibbled effect, rather than a deeply chipped texture. This method is more helpful towards minimising surface defects than say blasting, and is considerably cleaner than grit blasting.

    Bush-hammering is a similar process but the bush-hammer face has a deeply indented multi-pyramidal pattern. The hammer head is driven by a pneumatic, electric or hand hammer and the result is forgiving in that it can contribute to masking surface defects.

    A chiselled or pointed tool is used for jack-hammered surfaces. This system

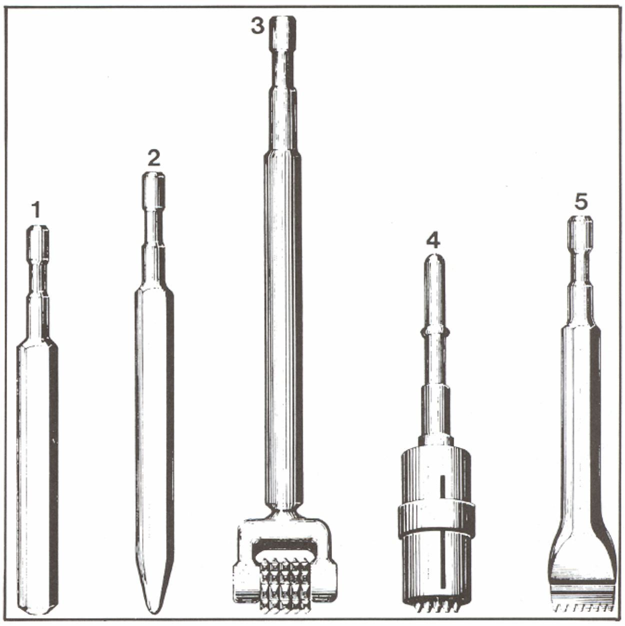

Figure 12: Tools used in creating finishes on hardened concrete: (1) and (2) – point tools: (3) – roller comb: (4) – bush hammer: (5) – comb chisel.

relies on fracturing the mortar and coarse aggregates for good effect and should be done after the matrix of fine aggregates and cement has reached the strength of the coarse aggregate. If hammering is carried out at an earlier stage there is the risk of knocking out particles of coarse aggregate rather than breaking them. The objective is to reveal the coarse aggregate particles and not to produce holes where particles had been. Chisel-type tools are better for fracturing across aggregate particles, while pointed tools tend to dig into the matrix (Figures 12 and 13).

Hammering of the nibs of a formed insitu or precast ribbed surface produces a robust vandal proof finish requiring little maintenance and having excellent weathering characteristics. The fractured ribs present an attractive, austere appearance with an emphasis on large scale texture (Figure 14).

It is always desirable to construct a prototype to investigate profile, concrete mix design, release agent, stripping time and optimum time for hammering. When finalised the prototype can be the reference standard for the job.

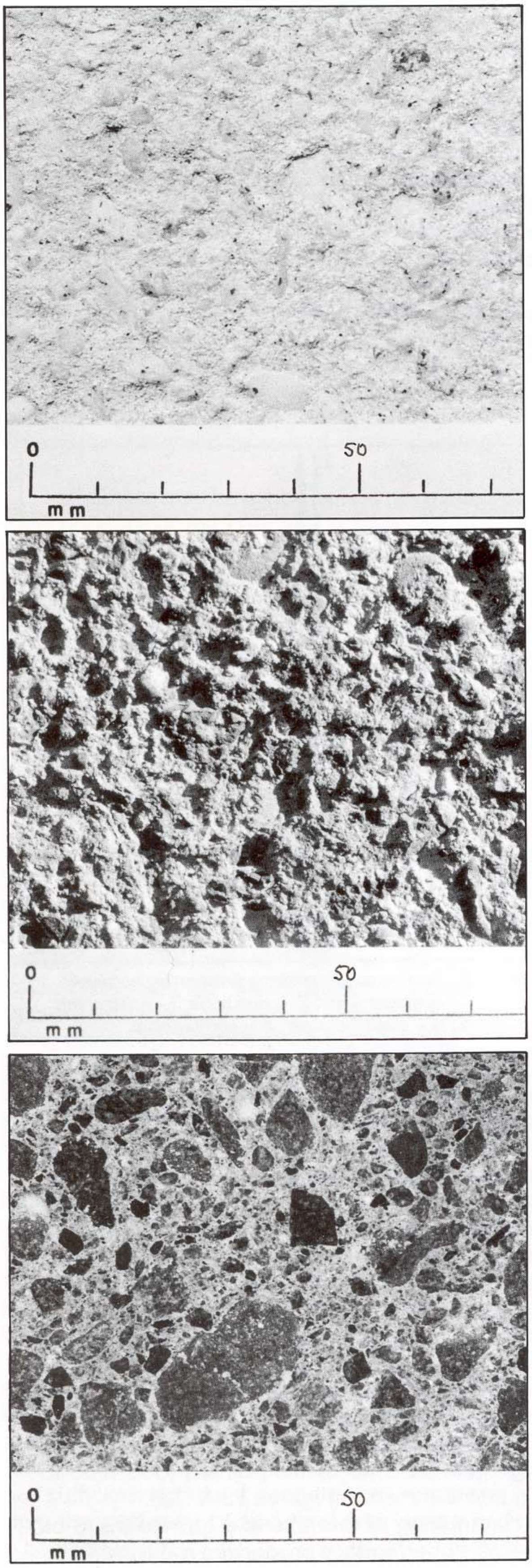

Figure 13: Different textures available using bush hammering or tooling.

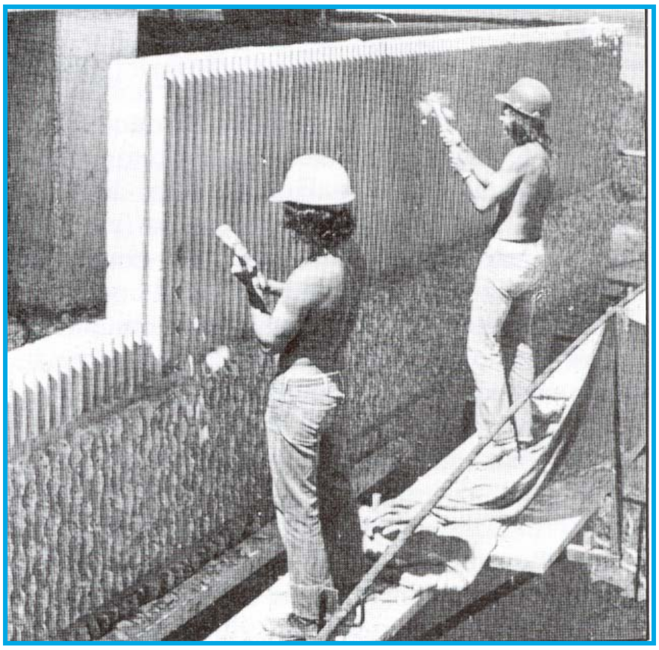

Figure 14: Hammered nib finish being completed.

Design considerations for this specialised finish are:

1. The selection of profile should be considered in relation to: readability at varying distances, the area of wall on which the finish is to be used in order to achieve the desired effect, the ability of the selected aggregate to penetrate the nib, stripping of forms, hammering by hand and unskilled labour as opposed to the use of pneumatic tools and skilled operators;

2. Selection of concrete to meet structural and visual requirements: selection of sand and cement to matrix colour will dominate finish, selection of aggregate size and colour including the colour of the fractured aggregate, and mix design to ensure a cohesive non-segregating mix with minimum bleed characteristics;

3. Materials and construction of watertight formwork;

4. Form oil-release agent must be selected to suit colour control;

5. Curing and stripping time. Curing time is a function of the gain of strength necessary to achieve fracture of aggregate when hammered and to prevent aggregate pop-out exposing only the matrix.

After a 14 day curing period it is found that it makes little difference when hammering is executed, and it may be done at a contractor's convenience. Many techniques can be used, but to obtain uniformity it is important that the set instructions be followed by all employed on the job. The actual hammering technique employed should be determined by the designer. It is possible to hammer in bands or with a random pattern depending on the appearance required.

Generally, because of the labour content, hammered surface finishes are usually more expensive than chemically-retarded and abrasive-blasted surfaces.

Cost of Finishes

The cost will vary significantly throughout the country, and depend both on the plant set-up (for precast units), the skill of the operators and a variety of other factors.

As a general guide the following list indicates a typical cost structure: (in ascending order of cost).

1. Smooth off-the-form finish.

2. Painted finish.

3. Retarded or water wash exposed aggregate formed liners; sand blasted.

4. Acid etched exposed aggregate; bush-hammered; hammered rib (fractured); ceramic/tiled faced.

5. Honed; polished; cut stone (veneered).

Finishing Techniques

In a large expanse of wall it is generally not possible to completely avoid surface blemishes or a requirement for cleaning down. In addition on wall formwork, there is generally a need to deal specifically with form tie rod holes.

Tie Rod Holes

If tie rods are the type that are entirely removed from the wall they should be pulled toward the inside face to avoid spalling the concrete on the exposed surface. The holes should be filled as soon as possible after stripping of formwork.

Tie holes should be filled solid with mortar using a grease gun of the plunger type such as those used on automobile transmissions. The flexible hose on the gun should be replaced by a short pipe for this purpose. Filling should be done from the inside of the wall. A piece of burlap or canvas should be held over the hole on the outside face and when the hole is completely filled the excess mortar should be wiped off with this cloth. No other finishing is necessary.

Where tie holes are to be filled and there is no colour match requirement, then the holes should be filled with a mortar mix consisting of 1 part of cement to 1 to 2 parts of sand passing a 4.75 mm sieve. Appearance can be enhanced in many cases by stopping the mortar filling of form tie holes about 2 or 3 mm from the surface. This requires properly aligned tie bolts, but the resulting effect is worth the slight effort required in setting out and placing the tie bolts. This recessed filling also relieves problems of colour differences and of smearing the surface as could happen with a flush finish.

Exact colour and texture matching for tie hole filling is virtually impossible to achieve. However, partial replacement of ordinary portland cement with white cement and the use of a light coloured sand can assist in reducing the colour differences between the concrete and mortar fill. Because of the colour/texture match problem it is recommended that holes be featured in some way such as described above.

Tie-rod holes left by removing only the outer ends of the rod so as to leave no metal closer than 35 mm to the surface, should be filled with a small tool that will permit filling the hole solid with mortar beginning at the back of the hole.

The mortar should be stiff enough to allow for ramming with a steel rod or some other suitable tool. This mortar should be cured for at least three days if possible.

Surface Dressing

A typical specification for bag rubbed surface dressing is as follows:

1. The concrete surface should be thoroughly pre-wetted then permitted to approach a surface dry condition.

2. The grout mix should consist of 1 part cement to 1½ to 2 parts fine sand. The sand should be clean and free of deleterious materials. White cement or white sand may be used in place of a proportion of the ordinary portland cement and sand. The grout should have the consistency of thick cream.

3. To fill all small air holes the grout should be rubbed thoroughly in a circular motion over the area with clean burlap or sponge rubber pads.

4. After the grout has stiffened sufficiently any surplus grout may be removed with a burlap or sponge rubber pad.

5. When visibly dry (after 2 hours) the surface should have a final rubbing down as in (4).

Note: Brushed on cement washes are not normally standard practice.

The sand should all pass a 600 μm sieve and not more than 10%' should pass a 150 μm sieve.

If it is necessary to remove fins of mortar projecting at formwork joints, care should be taken to avoid damaging the surface.

Excessive surface grinding can cause exposing of aggregate and the resulting change of texture may be unacceptable. Hand rubbing down to remove fins and rough patches using silicon carbide stones is recommended. Grade 36 stone is the most usual used but finer work can be achieved by finer stone grades.

Final hand rubbing with a piece of marble or No. 80 carbide stone can often produce an even, smooth surface.

Minor Repairs/Patching

Reference to the type of finish will indicate the requirements to match colour and texture of any repair in addition to the structural requirements of the filling or patch.

During construction every effort should be made to obtain a finish that does not require patching; patching adds to the cost of finishing and usually becomes more conspicuous with age. If well-made formwork has been properly erected, and concrete of proper workability has been well compacted during placing, honeycombing should not occur and patching should not be needed.

The extent to which it is safe to repair by patching depends upon the depth, position and extent of the honeycombing in relation to the size of the member. If reinforcement is exposed or the honeycombing occurs at vulnerable positions such as at the ends of beams or columns, it may be necessary to cut out the member completely, or in part, and reconstruct. A decision on the procedure to be adopted should be obtained from the engineer. If only patching is necessary, the defective concrete should be cut out to a depth of at least 25 mm or until solid concrete is reached, the edges being cut perpendicular to the surface, or if possible, with a small undercut.

An area extending several centimetres beyond the edges of the patch should be saturated with water before making good. A grout of equal parts of cement and sand should be brushed well into the surface to be patched, followed immediately by the patching concrete which should be well compacted with a wooden float and left slightly proud of the surrounding surface. Then, after an hour or more, depending on the weather, it should be worked off flush with a wooden float. A smoother finish can be obtained by wiping with hessian, cheese cloth or a similar soft material. A steel trowel should not be used because the smoothness produced will show, even through paint. Rubbing with a piece of marble will produce a finish texture similar to as-cast concrete.

The mix for patching should be of the same materials as those used in the concrete. Some reduction in maximum size of coarse aggregate may be necessary, and the mix may need to be richer in consequence. The mix should be kept as dry as possible. Where the surface is board-marked, this texture can be carried across the patch by striking off the surface with a straight-edge paralled to the direction of the marks.

Patches tend to be of a darker colour than the original concrete. Where this is of consequence, white portland cement should be substituted for some of the ordinary portland cement, the necessary quantity being determined by experiment, making comparisons when the samples have dried out. The proportion of white portland cement required varies from 10 to 30 percent of the total quantity of cement.

The patched areas should be kept moist for several days and prevented from drying out too soon. This is particularly important with patches made to repair honeycombed areas.

Structural repairs which are not covered in the scope of this bulletin are outlined in the CCANZ Information Bulletin IB 08.

Cleaning

Following the surface dressing procedures for stoning or bagging, it may be necessary to consider the removal of other stains.

Oil may be removed by using 5-10% solution of muriatic acid scrubbed onto the surface of a wetted concrete and subsequently well rinsed clean with water.

There should be no fins or mortar projecting between form boards or panels of plywood unless a rough texture is desired, but if there should be an occasional small fin that is objectionable it may be broken off carefully with a hammer.

Rough spots, stains and hardened mortar or grout can be removed by rubbing lightly with a fine abrasive stone (No. 36 or finer for a smooth finish) or hone. A hone used for sharpening tools will be satisfactory. Streaks caused by leakage from the lift of concrete above can often be removed by use of a hone. Plenty of water should be used, and rubbing should be sufficient only to remove the streaks without working up a lather of mortar or changing the texture of the concrete.

Summary

The finishing of concrete surfaces usually reflects the general workmanship and soundness of the construction. Although no more or less important than other phases of concrete work, the finishing is of importance to a much greater cross section of people than the actual core of the job. Not only the people directly affected by the job but also any observer, casually, or interested in the project in a specific way, will judge and pass comment, based on the visual finishing.

If the finishing of concrete surfaces is not correct in the first place remedial measures are few and expensive. Exposed concrete should have a high standard of finish, be it on floors, or walls, smooth or textured, but unfortunately this is not always the case. Exposed concrete surfaces can give a product that is almost maintenance free or maintenance intensive, that is profitable or costly, that causes satisfaction or argument, that gives pleasure or despair. The difference between good and bad concrete finishes is usually only a measure of proper specification, preparation, skill and care. Reference to Appendix B gives a summarised checklist which should prove to be of assistance to specifiers and constructors alike. Concrete can and should provide a long term maintenance free structure as well as a finishing material. Concrete is almost unique among building materials in meeting structural, protective and aesthetic requirements in the one product. However, good finishes do not just happen, consideration has to be given to a wide variety of aspects.

References

- NZS 3114 Specification for Concrete Surface Finishes SANZ 1980.
- Control of Blemishes in Concrete. W. Monks, Cement & Concrete Association, UK, 1981. (now British Cement Association).

APPENDIX A Blemishes in Concrete

Various types of blemish which can occur on concrete surfaces are described together with their probable causes in Tables A1, A2, A3 and A4 (from NZS 3114).

It is important for the specifier when preparing the specification, and the constructor when considering the methods necessary to meet the specification, to consider the probable causes of blemishes and their possible elimination or reduction. A photographic definition of some of the blemishes is contained in the Cement and Concrete Association, U.K., publication "Control of Blemishes in Concrete".

Table A1 Colour Variations (Early age of concrete)

Blemish	Description	Most Probable Causes
Inherent colour variation	Variation in the colour of the surface	Materials: Inconsistent grading, colour or source, aggregate transparency, material changes. Concrete: Incomplete mixing, segregation, or variation in proportions, ingredient omission.
Hydration discolouration due to moisture movement within or from the fresh concrete	Variation in shade of the surface	Formwork: Variable absorbency, through joints, variable vibration. Release agent: Uneven or inadequate application. Curing uneven.
Dye discolouration	Discolouration foreign to the constituents of the mix	Formwork: Stains, dyes or dirt on the form face. Release agent: Impure. Materials: Dirty.
Oil discolouration	Cream or brown discolouration	From construction plant. Release agent: Excessive; Impure (applied too late to the formwork). Timber or plywood inhibition.
Retardation	Matrix near the colour of sand and lacking in durability	Formwork: Retarder in or on form face; timber or plywood retardation. Release agent: Water soluble emulsion; cream or oil with excessive surfactant (surface active agent). Unstable cream; unsuitable or excessive chemical release agent.
Banding	Texture or colour variation showing in bands, generally in the horizontal planed in the members	Due to inconsistency in the concrete placement, stop-start methods in either conventional or slipforming concrete placing behind the forms, different hydration conditions.

Table A2 Colour Variations (Later ages of concrete)

Blemish	Description	Most Probable Causes
Drying discolouration	Variation in shade of surface from light to dark	Curing: Different conditions. Reinforcement: Inadequate cover.
Lime bloom or efflorescence	White powder or bloom on the surface	Design: Permitting uneven washing by rain. Leaching action. Release agent: Type. Curing: Uneven conditions.
Contamination	Discolouration foreign to the colour of constituent materials	Materials: Pyrites, clay or other impurities. Construction plant. Embedded steel: Inadequate cover, rust from steel above. Curing: Impure curing compounds, dirty covers.
Dusting	Light-coloured dusty surface, which may weather to expose aggregate.	Curing: Inadequate (very rapid drying). Vibration: Excessive vibration causing formation of laitance on surface. Excessive trowelling too early. Cement: Air-set. Release agent: Excessive application.

Table A3 Physical irregularities (Early age of concrete)

Blemish	Description	Most Probable Causes
Honeycombing	Coarse stone surface with air voids and lacking fines	Concrete mix: Insufficient fines; workability too low. Formwork: Joints leaking. Placing methods: Segregation, compaction inadequate. Design: Highly congested reinforcement, section too narrow.
Blowholes	Individual cavities usually less than 12 mm diameter. Small cavities approximately semi-spherical. Larger cavities often bounded by stone particles	Formwork: Form face impermeable with poor wetting characteristics; Inclined; Too flexible. Release agent: neat oil without surfactant. Concrete mix: Too lean; Sand too coarse; Workability too low. Placing methods: Inadequate compaction; Rate of placing too fast: Ineffective external vibration.
Grout loss	Sand textured areas devoid of cement, usually associated with dark colour on adjoining surface	Formwork: Leaking at joints, tie holes, stop-ends, and similar defects.
Scouring	Irregular eroded areas and channels having exposed stone or sand particles.	Concrete mix: Excessively wet; Insufficient fine particles; Too lean. Placing methods: Water in formwork; Excessive vibration on wet mix; Low temperature when placing.
Steps	Step, wave or other deviation from the intended shape	Formwork: Damaged, deformed under load; Joints not tightly butted – poorly designed. Placing methods: To rapid or careless.
Plastic cracking	Short cracks often varying in width along their length	Concrete mix: High water cement ratio; Low sand content; Uneven moisture retention prior to curing. Compaction: Uneven compaction ambient conditions leading to high evaporation rate and moisture loss from concrete. Reflective cracking above reinforcement due to insufficient concrete c over. Movement of partially set concrete; sloping conditions.
Form scabbling	Parts of the form face, including barrier paint, adhering to the concrete	Formwork: Form face excessively rough, weak or damaged. Release agent: Ineffective, inadequate application or removed during subsequent operations. Striking time: Too late.
Laitance	Milkiness – surface accumulation of porous weak cement paste	Pacing methods: Excessive vibration; Premature floating. Concrete mix: Unsatisfactory or excessively wet, or both.
Ridges or waviness	Physical deviations from the intended shape	Sideforms: Lack or rigidity. Finishing methods: Insufficient care during floating and screeding operations.
Dishing	Noticeable slumping of parts of surface	Placing: Uneven compaction. Finishing: Screeding and power floating techniques. Sub-base: Insufficient preparation.

Table A4 Physical Irregularities (Later ages of concrete)

Blemish	Description	Most Probable Causes
Scaling	Thin layer of hardened mortar removed from the concrete surface, exposing mortar or stone	Formwork: Relaxing after compaction; Form face excessively rough. Release agent: Ineffective application or removed during subsequent operations. Concrete: Low strength; Placing over vibration of high slump concrete. Striking time: Too early.
Spalling or chipping	Pieces of concrete removed from the hardened surface Deeper and usually more sever than scaling	Formwork: Difficult to strike. Release agent: Ineffective, inadequate application or removed during subsequent operations. Concrete: Low strength – aggregates susceptible to damage by frost or water. Striking time: Too early; Mechanical damage after striking. Weathering: Frost action – corrosion or reinforcement.
Crazing	A network of fine cracks in random directions, breaking the surface into areas from about 6 mm to 75 mm across	Formwork: Form face of low absorbency, smooth, or polished. Concrete mix: To rich in cement, too high water-cement ratio. Curing: Inadequate. Striking time: Too early, especially in cold weather. Compaction; Over vibration.
Scouring and abrasion	Surface material washed away by fluid action and surface material removed by rubbing action of solid bodies	Curing: Inadequate protection (water cure too severe, rainwater access). Concrete mix: Aggregates with insufficient abrasion resistance; lack of adhesion in mix; Segregation; Surface hardness treatment insufficient for purpose.
Holes	Irregular cavities	Concrete mix: Presence of soft, light materials such as wood and seedpods.
Warping	Deviation from the intended shape	Curing: Temperature and shrinkage differentials, and latter due to variation in water retention.
Shrinkage cracks	Usually transverse cracks, partly or wholly across slabs.	Concrete mix design: Water/cement ratio, aggregate/cement ratio; Incorrect design of slabs; Slabs unable to slide on sub-base due to excessive frictional resistance during curing; Saw cutting joints to late. Excessive moisture loss through surface or into sub-base. Inadequate protection during hydration and hardening.

APPENDIX B
A Checklist of Specification, Design and Construction Matters

Structural Detailing

1. Cracking can be minimised by specifying more, smaller diameter bars rather than fewer, thicker bars to provide the same cross-sectional area of steel reinforcement.

2. The reinforcement should be wired securely together or welded to form a rigid cage that will not be displaced during concreting.

3. The correct cover should always be provided. For ease of placing, it should be at least 1½ times the maximum size of the coarse aggregate.

4. The cover should be maintained by bar spacers, secured at regular intervals, or by battens that are withdrawn as placing proceeds.

5. All ends of wire ties should be turned inwards away from the face of the concrete. All loose ends should be removed.

Formwork

1. The formwork should be watertight and be capable of resisting the pressures generated during placing.

2. The formwork should be designed to limit any deflection. It should be rigid enough to prevent high-amplitude vibration during compaction. Variations in stiffness should be avoided so as to prevent differences in vibration across the form face.

3. All joints between sections of formwork and between formwork and hardened concrete must be carefully sealed. The use of tape or foamed plastic strips is recommended.

4. Formwork ties should be arranged in a regular pattern. They should be positioned to facilitate securing the formwork against leakage at construction joints.

5. When the primary requirement is for a concrete surface free from blowholes, formwork made from unsealed timber or plywood, hardboard or a water-absorbent lining is recommended.

6. When the primary requirement is for uniformity of colour of the concrete surface, it should be borne in mind that the absorptivity of the above-mentioned formwork materials will reduce with each successive use. Non-absorbent form materials such as steel can give concrete of uniform colour, but it is important to avoid the use of shiny, polished surfaces as these can produce variations in the colour of the concrete.

Release Agents

1. Release agents should be applied only to clean form faces. Clean brushes, cloths or sprays should be used.

2. The covering should be complete, uniform and very thin.

Cements

1. All the cement for one job should preferably be from the same consignment; it should certainly be from the same works.

Aggregates

1. The sand should be uniform in colour and grading throughout the contract.

2. The coarse aggregate should be obtained in separate sizes and recombined in the required proportions.

Mix Design

1. To obtain concrete with few blowholes, the sand content of the mix should be no higher than is necessary to avoid segregation and bleeding.

2. When the main requirement is for concrete of uniform colour, a somewhat higher sand content should be used.

Preliminary Contract Work

1. Trial mixes are essential.

2. Construction samples are necessary for verification of any untried details, and are valuable for 'training' and as an example.

Supervision

1. The quality of the finished work will be dependent upon the experience and the calibre of the supervisory personnel.

Weather Conditions

1. Extremes of temperatures may have an untoward effect on the concrete.

Batching

1. All materials except the mixing water should be batched by weight.

2. Due allowance should be made for the weight of water in the aggregates.

Mixing

1. Efficient mixing is essential. For visual concrete, longer mixing than is normal in ordinary concrete work may be necessary.

2. The workability of the concrete must be checked frequently.

Placing and Compaction

1. Equipment used for transporting the concrete must be clean.

2. Segregation and drying out must not be allowed to occur in transit.

3. Segregation must also be avoided during placing, which should continue without interruption from start to completion of a section. Walls, abutments and the like will have to be placed in layers but there should be no delay between layers.

4. The rate of placing should be uniform. It should exceed 2 m/h in vertical sections if possible.

5. Vibration must be continuous and begin at the bottom of each section of concrete as it is placed.

6. Internal (poker) vibrators are preferred.

Striking

1. The top of the concrete should remain covered until striking.

2. Striking times should be the same wherever possible - the target time for all vertical faces is two days.

3. After the formwork has been removed, the concrete should be protected from accidental damage.

4. All exposed surfaces should be covered with polythene sheeting to prevent drying out.

5. Rust from projecting reinforcement should be prevented from washing over the face of finished work.

Remedial Work

1. Remedial work is seldom entirely successful; the need for repairs should be avoided by taking greater care during construction.

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